

Protecting potable water from ‘forever chemicals’

Perfluoroalkyl and polyfluoroalkyl substances, collectively referred to as PFAS or “forever chemicals,” are being detected in water and many types of foods. **Viraj deSilva** of SCS Engineers provides an overview of sources, treatment processes used to remove them from wastewater, and government advisory limits.

The family of Perfluoroalkyl and polyfluoroalkyl substances (PFAS) – also known as “forever chemicals” – is extremely persistent in the environment. PFAS, which includes more than 4,500 synthetic chemicals, are organic compounds whose hydrogen atoms are replaced by fluorine. The bonds between fluorine and carbon are extremely strong and difficult to break. The two main PFAS compound structures are perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS).

Some PFAS are highly persistent and mobile in the environment and are bioaccumulative in humans. Recent studies by the Michigan PFAS Action Response Team Human Health Workgroup in the United States (US) found a correlation between high-PFOA exposure and six human health risks: kidney cancer, testicular cancer, ulcerative colitis, thyroid disease, hypercholesterolemia (high cholesterol), and pregnancy-induced hypertension.

So then, why are PFAS used in consumer products? PFAS lower surface tension and enhance spreading across the applied surface. They have high chemical and thermal stability between carbon-fluorine (C-F) bonds that provide stain-resistant properties for fabrics, carpets, food containers, and wrappers. They are also a flame retardant widely used in aqueous film-forming foams (AFFFs).

PFAS compounds have been continuously produced since they were developed in the 1940s. PFOA and PFOS are no longer manufactured or imported in the US, but similar replacement chemicals (such as GenX) remain. In 2000, 3M – a prominent manufacturer of PFOS – voluntarily phased the chemical out of production in the US. In 2006, PFOA began to be phased out as well. However, other countries still

manufacture PFAS and many consumer products imported to the US from those countries still contain the compounds.

About 610 locations in 43 US states serving an estimated 19 million people have PFAS in the drinking water, according to the Environmental Working Group and the Social Science Environmental Health Research Institute at Northeastern University in Boston, Massachusetts, United States (US). These locations are mainly near chemical manufacturing plants, airports, and military sites where firefighting foams containing the PFAS compounds are used in training exercises.

The current US Environmental Protection Agency (EPA) health advisory limit is 70 parts per trillion. However, as an advisory level, it is not enforced – meaning that the water is not required to be tested for PFAS compounds. There are numerous examples of PFAS chemicals found in groundwater used as a drinking water source, especially closer to airports and former PFAS manufacturing facilities. Meanwhile, various states established drinking water and groundwater guidelines for PFOA and PFOS.

EPA Action Plan for PFAS

In April 2019, the EPA announced a new PFAS Action Plan, which includes setting a maximum containment level (MCL) for PFOS and PFOA. Most of the current activity is focused on PFOA and PFOS because they have a long history of use in numerous products, and they have long elimination half-lives. However, the EPA plan will also address the broader spectrum of PFAS as many other fluorinated compounds are also used and are detected in water and food. The new plan will include the following steps: Start MCL process for PFOA and

PFOS, designate PFOA and PFOS as hazardous substances, consider adding PFAS chemicals to the Toxic Release Inventory.

PFAS contamination sources

There are four major sources of PFAS: fire training and response sites, manufacturing sites, landfills, and water resource recovery facilities (WRRF). Non-point sources may be associated with land-applied biosolids and atmospheric deposition. Other point sources of PFAS may exist, but generally are expected to be insignificant compared to these four main sources:

(1) *Fire training and response sites*: Contamination originates from AFFFs, a fire-extinguishing mixture used by the military, oil refineries, municipal airports, and fire stations. AFFFs contain highly diverse mixtures of PFAS.

(2) *Manufacturing sites*: These include manufacturing facilities that synthesized products containing PFAS, as well as secondary manufacturing facilities that used PFAS as a coating for finished products. Wind directions and atmospheric deposition play key roles in transporting PFAS from industrial manufacturing sites. PFAS can be detected in soil and water both upstream and downstream from a facility.

(3) *Landfills*: Industrial waste and consumer goods treated with non-stick coatings can all end up in landfills and ultimately the groundwater. Unlined landfills are more likely to disperse PFAS into groundwater, which can occur steadily over decades. These are mostly shorter-chain PFAS, which differ from those found at industrial and fire training sites.

(4) *WRRFs*: Possible reasons for PFAS occurring at these facilities include PFAS concentrations in solid waste and the oxidation of PFAS precursors during the treatment process.

Cycling PFAS between landfills and WRRFs

In a WRRF, biosolids generated during the secondary treatment of wastewater are largely removed before the discharge of the treated effluent. These biosolids are either used in agriculture to improve the quality of agricultural lands for crop production or disposed at a landfill. The application of biosolids is usually regulated under state and federal programs. If the facility receives wastewater from industrial discharges or leachate from domestic landfills, PFAS may be present in the treated effluent or generated biosolids. PFAS have been discovered in soils amended with biosolids, according to a 2011 report, “Occurrence and fate of

Established PFOA and PFOS guidelines for groundwater in several US States.

State	PFOA	PFOS	Source
Delaware	0.40	0.20	DNREC, 2016
Maine	0.13	0.56	MDEP 2016
Michigan	0.42	0.011	MDEQ, 2015
Minnesota	0.035	0.027	MDH, 2017
New Jersey	0.04	NA	NJDEP, 2016
North Carolina	2.0	NA	NCDEQ, 2013
Texas	0.3	0.6	TCEQ, 2016
Vermont	0.02	NA	VTDEC, 2016

perfluorochemicals in soil following the land application of municipal biosolids.”

The PFAS relationship between WRRFs and landfills is growing more complicated. The WRRFs hesitate to accept landfill leachates, and landfills refuse to receive biosolids from these facilities because of this emerging contaminant. In the US state of Vermont, if the PFAS exceed a certain level, the leachate needs to be pre-treated before local publicly operated treatment works (POTWs) will accept it.

PFAS removal

Conventional treatment methods won't remove PFAS. As more US states continue to move forward with tighter regulations of PFAS, other states will follow. Many universities and research and development (R&D) institutions are developing new and emerging technologies to produce a long-term solution to managing PFAS. It is important to forge relationships with these institutions early and to stay in communication as regulations take shape and more effective technologies become available.

PFAS present a significant treatment technology challenge because of their properties, diversity, numbers, and usually low parts per billion (ppb) and parts per trillion (ppt) environmental presence. Water treatment technologies for low-level concentrations include granular activated carbon (GAC), reverse osmosis (RO), anion exchange (IX), and possibly advanced oxidation (AO).

Granular activated carbon: GAC is widely used in water treatment to remove or adsorb organic molecules like PFOS and PFOA. GAC adsorption capacity depends on influent water quality and the treatment effectiveness of GAC may be influenced by pH, water temperature, flow rates, contact time, and the presence of organic and inorganic compounds in the water. GAC is capable of removing longer-chain PFOS compounds. The various types of GAC have different efficacies and capacities. Reported removal rates above 90 percent result in end water concentrations at very low ppt and no detectable levels, and with usually longer-than-typical empty bed contact times and frequent bed replacements.

Anion exchange (IX) processes: The treatment and removal of PFAS via IX primarily involves anion exchange. Effectiveness of IX treatment is influenced by pH,

water temperature, flow rates, contact time, and presence of organic and inorganic compounds in the water. Specifically, for PFAS removal using IX, water with high concentrations of total dissolved solids (TDS), iron, other dissolved organics, sulfates, chlorides, and competing anions, as well as potential foulants and scalants, can potentially hinder the treatment and performance of IX resins. The brine produced by the regeneration process requires proper disposal. Some waters will require pre-treatment because competitive water composition factors can affect removal efficiencies, including other anions.

Reverse osmosis (RO): Generally effective for removing PFAS compounds, RO has achieved a more than 99-percent removal of PFOS and PFOA from drinking water and 90-percent removal from some wastewater. RO requires pretreatment in many applications, but perhaps not as much when applied to otherwise high-quality groundwater. The process generates reject water with accumulated PFAS chemicals that requires proper disposal. Reject water volumes may range from up to 25 percent of the input, depending on the water composition, specific membrane and design, and operating pressures.

Concentrated PFAS waste management: Most of the established PFAS treatment processes produce concentrated PFAS waste that needs to be handled appropriately. The most proven method is to incinerate this waste above 1,000 degrees Celsius (1,800 degrees Fahrenheit), which will destroy the PFAS compounds completely. Current research is underway to investigate other possible methods, such as electrochemical treatment.

Summary

The US Food and Drug Administration (FDA) confirmed that forever chemicals were detected in many foods. The FDA tested 91 foods, including fresh produce, baked goods, meat, and fish. PFAS chemicals were found in sweet potatoes, pineapples, leafy greens, chocolate cake with icing, ground turkey, oven-roasted chicken, and boiled shrimp.

Perfluorinated chemicals will continue to be subject to studies, risk assessments, possible regulations, and data collection under several statutes, so product- and waste-reduction practices should be considered immediately to reduce

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potential consequences. Many US states have adopted the EPA Health Advisory limits, or lower. It is still undecided whether the PFAS issue requires a national drinking water MCL under the Safe Drinking Water Act.

The EPA Health Advisories in place are essentially MCL Goals. However, understanding the potential health and economic benefits of having national standards for drinking water should generate an immediate effort to obtain drinking water data for PFAS chemicals

from all groundwater supplies. Even though forever chemicals have been identified for over 20 years, the regulations to protect drinking water have not been in place. It is hoped that the new EPA Action Plan will resolve this long-standing issue. Importing consumer products containing PFAS from other countries must also be banned. These measures will lead to better protection of potable water from the harmful impacts of forever chemicals.

Author's Note



SCS Engineers' Wastewater Treatment Director Dr. Viraj deSilva has 30 years of experience in the evaluation, sizing, and design of treatment processes for water, wastewater, leachate, and solids-handling facilities. He has conducted projects in 12 countries and serves on several national PFAS technical committees. Currently, Dr. deSilva serves as the Landfill Management Division vice director in the Solid Waste Association of North America (SWANA) and

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